

Final Report

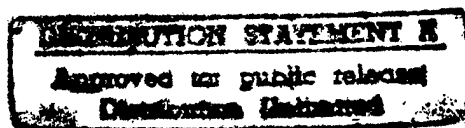
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OptiMETRICS, INC.
Research & Engineering

MultiSIM-IDS - A
DIS-Compliant Simulation of
INTEGRATED DEFENSE SYSTEMS

Prepared For:

U. S. Army Tank-automotive and
Armaments Command
Warren, Michigan 48397-5000



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13. ABSTRACT (Maximum 200 words) MultiSIM-IDS is a new DIS-compliant simulation that allows the addition of Integrated Defense System (IDS) capabilities to existing manned simulators or ModSAF entities. IDS systems provide a coupled suite of sensors, countermeasures (CM's) and countermeasure employment rules that work to automatically (or semi-automatically) protect military vehicles from incoming projectiles. MultiSIM-IDS allows the simulation user to select various sensor types (launch, tracker or laser warning), various countermeasure types (smoke, EO missile countermeasure devices, laser decoy devices, or active protection systems) and CM prioritization logic. The simulation allows specification of the functional performance parameters of the system components (e.g., sensor detection range, CM effectiveness parameters, etc.) by the user. During a DIS exercise, the IDS capabilities can be assigned to selected battlefield entities (i.e., M1A2 tanks) and the simulation will "defend" those entities from specified types of threat munitions. The simulation can also provide warnings and situational awareness information for the crews of manned simulators. An initial version of the MultiSIM-IDS simulation was used in the Force Protection Experiment III at the Mounted Maneuver Battle Lab during the fall of 1996. The final version of the software was delivered to TARDEC in February of 1997.				
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1.0 EXECUTIVE SUMMARY

1.1 INTEGRATED DEFENSE SYSTEMS

An Integrated Defense System (IDS) provides a coupled suite of sensors, countermeasures (CM's) and countermeasure employment rules that work to automatically (or semi-automatically) protect military vehicles from incoming projectiles. At the present time, most IDS systems are in research or developmental stages; thus, there has been little experience with such systems in the field. MultiSIM-IDS provides the capability to explore the value of various IDS system components in simulation before these systems are placed in the field. It also provides an ability to develop operational tactics in parallel with the hardware system development through the use of simulation. IDS systems are also called Hit Avoidance (HA) systems or Defensive Aide Suites (DAS). Figure 1 illustrates the functioning of a generic IDS system.

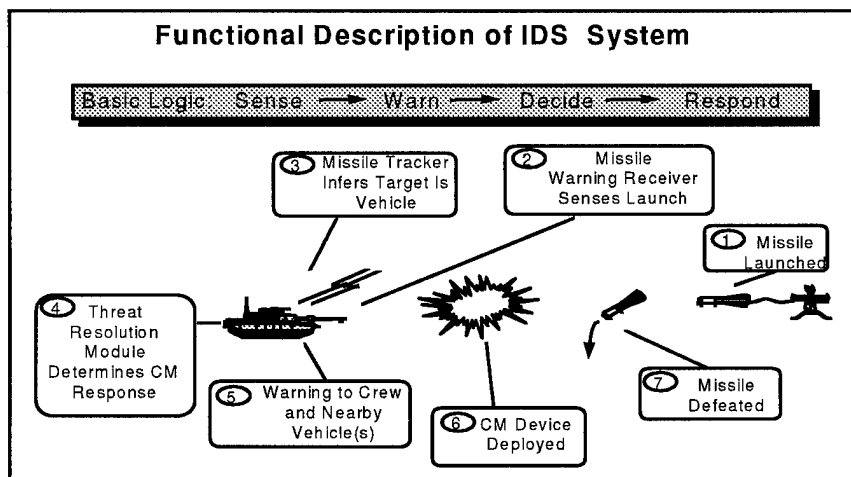


Figure 1. Functional description of an IDS system.

In this project we have developed a simulation specifically tailored to simulate IDS systems for ground vehicles; however, similar defensive systems exist for fixed wing and rotary wing aircraft. IDS systems can include various sensor types (launch, tracker or laser warning), various countermeasures types (smoke, EO missile countermeasure devices, laser decoy devices or active protection systems) and CM prioritization logic. A simple IDS system may consist of just a missile launch detector and smoke. A more complex system could include all three sensor types and multiple kinds of countermeasures. An IDS system may also include crew warnings, crew tactical reactions to threats, and crew control or prioritization of CM's. Only simple IDS systems (or individual warning sensors or CM's) have currently been deployed on ground vehicles. More complex systems are being designed and

evaluated for future vehicles. MultiSIM-IDS provides an important tool to design and evaluate future systems.

1.2 MultiSIM-IDS SIMULATION

The Integrated Defense System (IDS) simulation is the second DIS-based simulation developed by OptiMetrics using the MultiSIM software development architecture. A main feature of the MultiSIM architecture is development of the simulation using a reusable set of C++ modules that are connected together to form the complete simulation. Once these modules have been developed, a text-based "connections file" defines the paths by which information flows between the various modules. There are a number of advantages of software development with this design including:

- Facilitation of software reuse.
- Enforcement of modular code development.
- Ease of debugging.

In fact, about 30% of the modules included in the MultiSIM-IDS simulation were developed on an earlier program.¹ The initial version of MultiSIM-IDS was completed in less than three months following completion of the software design.

The MultiSIM architecture also provides advantages in the use of the complete code:

- An explicit, user understandable, representation of how data flows through the various code modules.
- The ability to reconfigure the software without rewriting or even recompilation of the source code.

The latter feature allowed MultiSIM-IDS to simulate the defense of four manned simulators and ten ModSAF vehicles, using a single SGI workstation, by configuration of the same modules developed to simulate the defense of a single vehicle.

1.3 APPLICATIONS OF MultiSIM-IDS

During a DIS exercise, the IDS capabilities can be assigned to selected battlefield entities (i.e., M1A2 tanks) and the simulation will "defend" those entities from specified types of threat munitions. The simulation can also provide warnings and situational awareness information for the crews of manned simulators. An initial version of the MultiSIM-IDS simulation was used in the Force Protection Experiment III at the Mounted Maneuver Battle Lab.

¹ Smith, F.G., G. H. Lindquist, and J. I. Montgomery, "MultiSIM-DIS Model for SIGINT Sensor Simulation in DIS," *13th Workshop on Standard for the Interoperability of Distributed Simulations*, October, 1995.

For the future, MultiSIM-IDS provides a platform for detailed simulation of the components of IDS systems, or indeed many types of sensor systems. Higher fidelity models of sensors, countermeasures or the threat resolution logic could easily be added to the current simulation. The extension of MultiSIM-IDS to simulate a Distributed-IDS system has also been proposed.

2.0 MULTISIM-IDS SIMULATION FUNCTIONAL DESCRIPTION

MultiSIM-IDS includes modules that simulate various types of sensors, countermeasures and response logic. The modules are generic in the sense that parameter inputs determine the effective ranges of the sensors, the effectiveness of the countermeasures, angular coverage and other similar system properties. A Threat Resolution module is also included that provides for a fixed prioritization of the countermeasures and for the effective use of the available countermeasures to defeat various types of threats. Figure 2 provides an overview of the various components of the MultiSIM-IDS simulation.

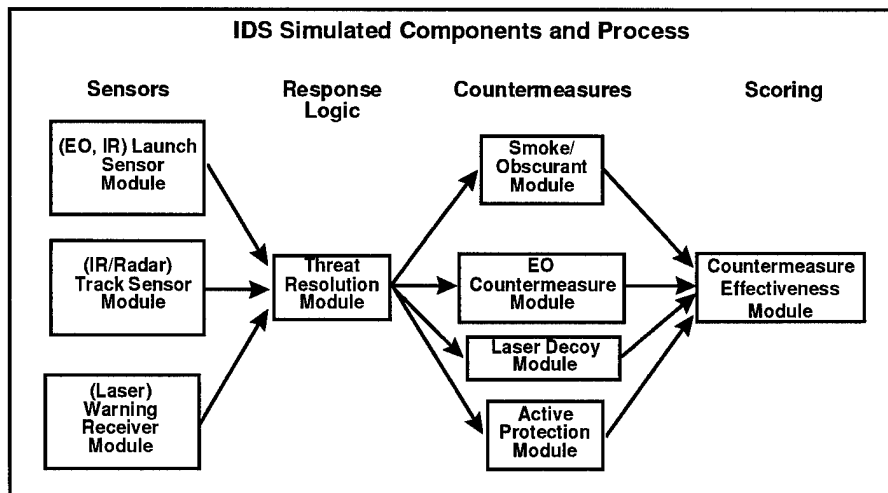


Figure 2. IDS simulated components and process.

The functioning of the various component modules is determined by parameters specified in input files (.init files) read at execution time. Those parameters are described in the MultiSIM-IDS User's Manual.² The following paragraphs summarize the algorithms used in the various modules of the simulation.

2.1 SENSORS

MultiSIM-IDS includes modules to simulate the performance of three classes of sensors: launch/flash sensors, tracking sensors and laser warning sensors. All sensors utilize DIS entity state information to determine in real-time the location of the sensors and the threats. Threat visibility also considers line-of-sight blockage by terrain. Atmospheric effects are not explicitly considered in the simulation. If atmospheric effects are important for a

²Smith, F.G., A.W. Dunstan, G. H. Lindquist, *MultiSIM-IDS HA-DIS User's Manual*, OMI-585, OptiMetrics, Inc., January 1997.

particular scenario, that can be represented as a degraded detection range for the affected sensor types.

A Flash Sensor module simulates the IR/optical observation of the launch flash of a missile or muzzle flash of a main gun firing. Since the flash observed is a nearly instantaneous event, no projectile tracking information can be obtained from the flash sensors. However, munition classification information may be available from the spatial, spectral and temporal characteristics of the flash event. The MultiSIM-IDS sensor module allows the user to select various parameters, such as the effective detection, classification and identification ranges of the flash sensor, to tailor the system's performance to emulate the characteristics of a specific device. The decision on the detection/ classification/ identification of a projectile is made only once, at the time of launch, by the flash sensor. Other parameters that can be specified for the flash sensor include field of view (FOV) and processing delay time.

The tracking sensor module simulates a sensor that is able to develop a track of a threat munition through a portion of its flight. An infrared search and track sensor or a radar sensor are examples of such systems. Similar to the flash sensor, the tracking sensor allows the user to input parameters that specify the performance of the tracking sensor, including function ranges, FOV and processing delays. The tracking sensor also includes parameters to represent trajectory estimation and hence infer an "I am the target" determination. The track determination is modeled using a Fuzzy Logic function related to the length of time a threat munition has been tracked. As the tracking time exceeds an input threshold, a determination that "I am the target" becomes more certain.

The third type of sensor represented is a laser warning sensor. The laser sensor represents a system that can determine when a vehicle is illuminated by a laser rangefinder, laser designator or beamrider missile laser beam. The laser sensor has only one range parameter, classification range. For this sensor, it is assumed that detection and classification occur simultaneously. Classification refers to a determination of whether the illumination is from a rangefinder, designator or beamrider. With the laser sensor, an "I am the target" determination is also assumed to occur with classification. The laser sensor input parameters also include FOV specification.

2.2 THREAT RESOLUTION

The threat resolution module's responsibility is to process the output reports from the sensors and determine the appropriate countermeasure response to the sensed threat. On this project, there was no attempt to develop a sophisticated threat resolution module; other

projects at TARDEC are pursuing such developments. The present software uses a simple prioritization scheme to determine countermeasure reactions. Only automatic countermeasure responses are simulated in MultiSIM-IDS. The MultiSIM-IDS threat resolution logic follows the rules outlined below:

- No countermeasures are deployed until a classification and an "I am the target" determination is made by one of the sensors.
- Only a countermeasure expected to be effective against a particular threat type is deployed against such a threat.
- The countermeasures are deployed in the following priority:
 - Missile Countermeasure Device (MCD)
 - Laser Countermeasure Device
 - Active Countermeasure System
 - Smoke/Obscurant System.
- The first countermeasure expected to be effective against the current incoming threat is used, unless otherwise engaged.
- A countermeasure is not deployed if there is already a countermeasure in effect that is expected to counter that threat.
- A countermeasure is not deployed if the threat has passed (i.e., missed) the defended vehicle.

The fact that a countermeasure is deployed against a threat, does not mean that a countermeasure will always be effective. The countermeasure effectiveness is determined by another module, based on the time the countermeasure has to act on the threat and the probability of effectiveness of the countermeasure.

2.3 COUNTERMEASURES

At this time, four types of countermeasures are represented in MultiSIM-IDS: smoke/obscurants, an EO Missile Countermeasure Device, a Laser Designator Decoy Device, and an Active Protection System. As with the sensor, MultiSIM-IDS does not attempt to model the physical details of each countermeasure, rather it attempts to represent the functional performance of these devices. Additional representation details could be added in the future, if it is determined that they are necessary for a particular exercise or experiment.

2.3.1 SMOKE/OBSCURANT SYSTEM

The smoke/obscurant countermeasure system is represented as screening the vehicle from a defined sector, for a specified period of time. No wind interaction is represented. The parameters of the smoke system include deployment direction, smoke screening radius, distance to cloud center, smoke cloud duration, and detonation delay. The radius is the "radius" of the smoke cloud parallel to the ground and distance is the distance of the cloud

from the center of the vehicle. The simulation assumes that the entire azimuth sector defined by the smoke cloud radius and distance is screened. The delay is the length of time after the deployment command that is required for the smoke screen to become effective. The duration is the length of time the screen remains effective.

Multiple screens can be represented, and a number of reloads can be specified. For example, the M1 could be reasonably represented as having two independent screens (left-front and right-front) and two loads available for each screen.

2.3.2 EO MISSILE COUNTERMEASURE DEVICE

The EO Missile Countermeasure Device (MCD) is a countermeasure effective against certain EO command-to-line-of-sight guided missiles. The system requires a beam to be pointed in the direction of the incoming missile to defeat the munition. The size of the MCD FOV is defined by input parameters. The device is effective if the incoming missile is within its FOV for a given amount of time.

A slewable MCD can also be represented. Two additional parameters are used in the slewable version of the MCD: SlewRate, in degrees per second, and AssignmentDuration, in seconds. The Slew Rate is the average rate at which the device can move to point in the direction of an incoming threat. The device is assumed to be able to rotate about the z-axis. The Assignment Duration is the time that the MCD will be pointed in the direction of the threat after slewing. The device will not respond to a new threat (outside its angular coverage) until the Assignment Duration for the present usage has passed.

2.3.3 LASER COUNTERMEASURE DEVICE

A Laser Countermeasure Device (LCD) is any countermeasure effective against a laser guided munition. Its main purpose is to represent a laser repeater or decoy device that illuminates a nearby terrain patch and thus causes a laser-designator guided missile to hit the illuminated terrain rather than the defended vehicle. The LCD device parameters are similar to the parameters for the MCD system. The LCD can also be a slewable device.

2.3.4 ACTIVE PROTECTION SYSTEM

An Active Protection System (APS) describes a countermeasure device that physically interferes with the functioning of an incoming munition. Typical APS systems utilize "shotgun" pellets or a guided projectile to intercept an incoming round. The simulation for this device contains the following parameters: SlewRate, FlightDuration, NumberofGrenades and AverageEffectiveness.

2.4 COUNTERMEASURE EFFECTIVENESS DETERMINATION

The nature of DIS allows an retroactive determination of countermeasure effectiveness by the IDS simulation. When a Detonation PDU is received indicating a (potential) munition impact on a defended vehicle, a determination is made if a countermeasure has been deployed against that munition and if that countermeasure was effective. Countermeasure effectiveness is determined using the following rules. First, certain types of countermeasures are only effective against certain types of munitions. MCD and LCD countermeasures are only effective against EO guided and laser guided missiles, respectively. Smoke/obscurants are considered effective against all types of missiles. The APS system is effective against either missiles or main gun rounds. No countermeasures except an APS system is effective against main-gun rounds.

Given the matching threat type, the effectiveness determinations for the MCD, LCD and smoke/obscurant countermeasures are similar; if the countermeasure has been effectively deployed against the munition for a given time-duration (an input typically set as 2-3 seconds), then the countermeasure is determined to be effective. The APS system is assumed to be effective, with a given probability, if it has been effectively deployed against the munition.

Countermeasures will not always be effective for many realistic reasons. If a slewing countermeasure (MCD or LCD) is engaging one threat, it will not be available to defend a threat from a different direction. Close-in or high-speed missiles may not be defeated because there is not time for the countermeasure to deploy. Smoke/obscurant countermeasures require a finite time to become effective. The APS system is modeled as effective for only a certain percentage of engagements. Both smoke/obscurant and APS systems are limited by the number of reloads available. Finally, the IDS system will only be effective against threats which are defined as defensible in its "Defensible Munitions" input file.

3.0 MultiSIM-IDS SOFTWARE IMPLEMENTATION

3.1 SIMULATION ARCHITECTURE

A simplified version of the software architecture of MultiSIM-IDS is illustrated in Figure 3. Each box in that figure represents a separate C++ module (object). Most connections between the various modules are also shown on the figure. This structure enforces the main tenants of object-oriented design: localization of functions within class objects and well-defined interfaces between objects of different classes.

The data transfer between modules is made via software ports that are actually connected at execution time based on the instructions in a "Connections File." This is a very flexible mechanism that allows configuration of various IDS systems using the same software components.

The Simulation Manager Module initiates the simulation and generates internal timing information that is used by most modules of MultiSIM-IDS. A main function of the Simulation Manager is to "connect" the various IDS modules using the information contained in the Connections File. It also provides for the initialization of the parameters of the various modules via the ".init" initialization files. The commercial VR-Link software runs in the background and provides access to the DIS network connection, monitoring entity state PDU's and dead reckoning to the entity locations.

The main MultiSIM-IDS software components are triggered by PDU's received over the DIS network, plus internal timing events. The cycle is started when a Fire or Laser/Designator PDU is received. The PDU notification is converted to an OMI (internal) event by the Converter module and passed either to the Designator Event Manager (for Laser/Designator PDU's) or the Movement Event Manager (for Fire PDU's). The event managers create designator or movement events at defined intervals (typically 0.1 seconds) that drive the sensor and countermeasure modules. At each event tick, each sensor is polled to determine if it can see the threat (or laser). If so, it creates or updates a track file on each threat. Also, at each tick, the Threat Resolution Module reviews the threat files to determine if it has enough information to attempt to deploy a countermeasure against that threat. If a countermeasure action is appropriate, the Threat Resolution Module polls the countermeasures to determine if any are already deployed that should be effective against that threat, and if any are available for deployment. If an appropriate countermeasure is available, the Threat Resolution Module will tell a Countermeasure System to deploy it. The Threat

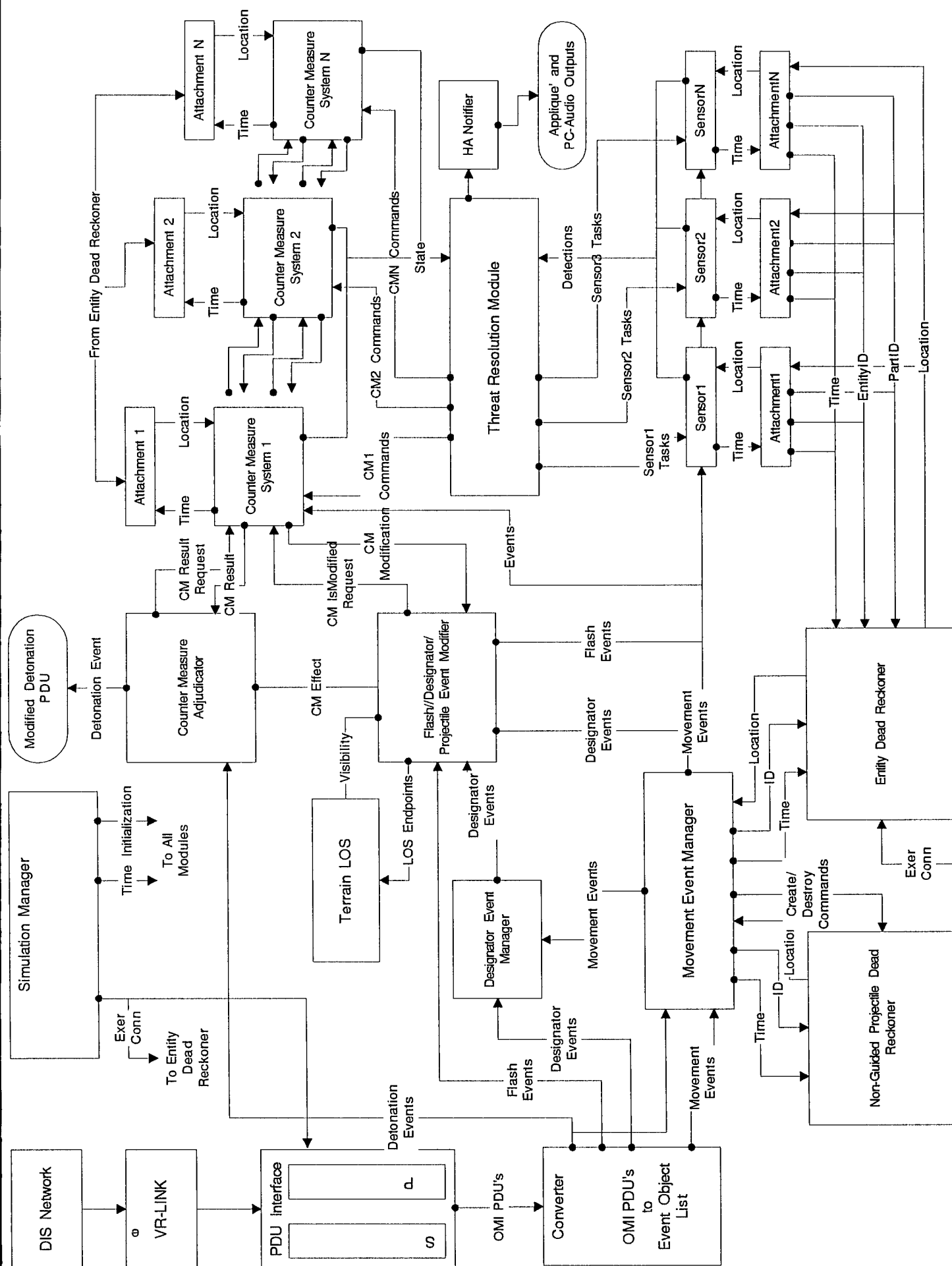


Figure 3. MultiSIM-IDS Software Architecture.

Resolution Module also causes the issuance of status messages, via Data PDU's, that notify other network entities (e.g., Appliqué Simulation) of the detection of threats or the deployment of countermeasures.

A second cycle is driven by receipt of a Detonation PDU. If a Detonation PDU is received that indicates the Defended Vehicle would have been hit by a munition (in the absence of countermeasures), that triggers a determination by MultiSIM-IDS of the effectiveness of any countermeasures deployed against that munition. That determination is performed by the Countermeasure Adjudicator Module. The Countermeasure Adjudicator Module monitors at each movement event time step which, if any, countermeasures are effective against each munition. When triggered by the Detonation event, the Countermeasure Adjudicator Module determines the total time countermeasures were effective against that munition, and if that time is greater than an input threshold parameter, it emits a new Detonation PDU. If the countermeasure was determined to be effective, the new Detonation PDU indicates a munition miss. If the countermeasures were determined not to be effective, the new Detonation PDU indicates a hit, as in the original Detonation PDU.

3.2 INTEGRATION WITH MANNED SIMULATORS AND MODSAF ENTITIES

3.2.1 INTEGRATION WITH MANNED SIMULATORS AND MODSAF ENTITIES

MultiSIM-IDS adds simulation of an Integrated Defense System to existing DIS manned vehicle simulators or semi-automated forces. The main function of an IDS system is to prevent the defended vehicle from being hit/killed by incoming munitions. To accomplish that in simulation, MultiSIM-IDS evaluates Detonation PDU's issued by the threat simulators, before they are processed by the defended vehicle. If the munition is determined to have missed as a result of the simulated IDS system, a ground impact Detonation PDU is issued. If the IDS system was unsuccessful in defeating the incoming munition, a validated version of the original Detonation PDU, indicating defended vehicle impact, is issued. For this scheme to work, one change needs to be made to the manned simulator or ModSAF software; their damage tables need to be modified so that only validated Detonation PDU's are processed. Detonation PDU's are validated by setting munition ID's "Special" field to "1". The user must change the damage tables for the defended vehicles so that only Detonation PDU's with the Special field set to 1 cause damage.

3.2.2 INTEGRATION LESSONS LEARNED WITH RESPECT TO INTERFACE TO MODSAF

In the course of the code development, we encountered a number of problems where ModSAF-generated PDU's or data did not conform to DIS standards or otherwise caused problems with our simulation. ModSAF problems encountered included:

- The Munition (entity) ID was omitted from the Fire PDU's issued by ModSAF.
- An Entity Creation PDU was not issued for the newly created entity (the missile).
- The velocity vector given in the Fire PDU for a main gun round did not aim the round directly at the target, but causes it to fly under the target.
- When a laser rangefinder illuminated the target, a Designator PDU was issued, but many of the PDU fields (for example power and wavelength) that should be set were not, and hence defaulted to "zero."
- A laser designator illumination causes a string of PDU to be issued, but with no indication of the last PDU in the sequence.

Each of the above seems a small item, however, because they were unexpectedly encountered in debugging our software, and most necessitated a "work-around," they significantly added to our development effort. Some of the problems may have been corrected in the latest versions of ModSAF, but because ModSAF is so widely used in DIS exercises, it is imperative that it strictly conform to the DIS protocols.

3.3 APPLICATIONS AND BATTLE LAB TEST AND EVALUATION

3.3.1 APPLICATION IN THE FPE-III EXPERIMENT

An initial version of MultiSIM-IDS was used as a component of the Force Protection Experiment III, performed by the Mounted Maneuver Battle Lab. The FPE-III experiment was performed at the Mounted Warfare Test-Bed (MWTB) during the fall of 1996. The configuration of MultiSIM-IDS as used in FPE-III is illustrated in Figure 4. In that experiment, MultiSIM-IDS simulated an IDS system consisting of a missile warning receiver, an EO missile countermeasure device and smoke/obscurant countermeasures. The simulation was used to "defend" four manned simulators and ten ModSAF vehicles. In addition to the IDS system, FPE-III included simulations of a developmental combat identification system, E-BCIS, and a battlefield situational awareness display, Appliqué.

In FPE-III, the IDS simulation provided audio warning of incoming rounds and countermeasure defense against threat missiles. IDS warnings of missile launches and main gun firings were shared among the crews of the manned simulators via feeds to the situational awareness displays provided by Appliqué. The interfaces between the IDS simulation, a PC

that provided manned simulator audio, and Appliqué were provided by the MWTB contractor, Lockheed-Martin, and its subcontractor, SAIC.

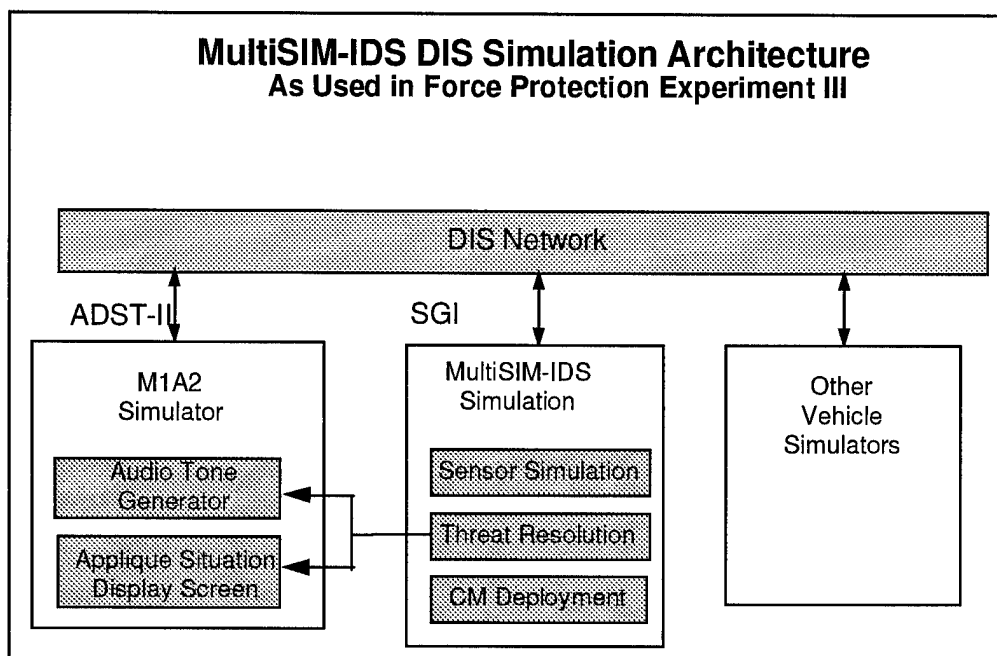


Figure 4. MultiSIM-IDS DIS simulation usage in FPE-III.

The formal analysis of the experiment is not yet available; however, the IDS simulation operated with no problems throughout the six-week experiment. There also were lessons learned in the setup and initial configuration of the experiment. One issue addressed in generation of the audio warnings was that the data needs to be filtered before presentation to the crew. The IDS system is able to generate multiple reports as a single missile is first detected, is classified, is determined to be aimed at a particular vehicle, is countermeasured, etc. The crew is not able or interested in that wealth of information; a single warning that an incoming munition has been detected and the angle of the incoming round is sufficient information for the crew. A second issue addressed was that Appliqué's formats do not support display of a simple line-of-bearing (LOB) report, to indicate incoming missile direction. Because of that limitation, IDS LOB reports had to be approximated as spot reports for Appliqué, with an assumed range of 2.5 kilometers from the defended vehicle.

With the above issues addressed, the IDS simulation functioned well throughout the FPE-III experiment. The soldier crews were pleased with the information obtained via the IDS system and expressed disappointment when the IDS system was not used in a particular trial.

3.3.2 MultiSIM-IDS SOFTWARE TEST AND EVALUATION

The complete MultiSIM-IDS simulation is scheduled for a formal Test and Evaluation by TECO at the Mounted Warfare Test Bed at Ft. Knox during February 1997. The results of that testing are not yet available. Internal testing at OptiMetrics facilities during January 1997 indicates that all modules are functioning correctly. Preliminary testing of a limited capability version of MultiSIM-IDS was performed at the Battle Lab prior to the FPE-III experiments. The IDS simulation performed correctly during those tests.

4.0 SUMMARY AND RECOMMENDATIONS

4.1 PROJECT SUMMARY

The MultiSIM-IDS simulation has been successfully developed, tested, utilized in a Battle Lab experiment, and delivered to TARDEC and the Mounted Maneuver Battle Lab. MultiSIM-IDS provides a very flexible capability to simulate a variety of sensors and countermeasures as components of the IDS systems, within a DIS simulation environment. The design of the IDS simulation allows the user to configure the software to simulate various IDS systems and to set parameters that govern the operation of the individual sensors and countermeasures. MultiSIM-IDS provides a flexible tool for future Battle Lab experiments.

4.2 RECOMMENDATIONS FOR FUTURE MultiSIM-IDS DEVELOPMENTS AND APPLICATIONS

A proposed project would extend the MultiSIM-IDS system to allow the simulation of Distributed Integrated Defense Systems. A Distributed-IDS system would spread the IDS components over a number of platforms (e.g., the vehicles in a platoon) and link them together via communications network. Potentially, that could make IDS systems more affordable, because expensive sensors and countermeasures would not have to be duplicated for every vehicle in the force.

MultiSIM-IDS also provides a platform for detailed simulation of the components of IDS systems, or indeed many types of sensor systems. Higher fidelity models of sensors, countermeasures or the threat resolution logic could easily be added to the current simulation. The current version of the simulation uses automatic deployment logic for the countermeasures. An extension of the simulation could allow for display of warnings to the crew and semi-automatic (crew-managed) deployment of countermeasures.

As the simulation currently exists, it could be directly used in tradeoff experiments at the MWTB to determine an optimum suite of sensors and countermeasures for a particular vehicle application. Because the MultiSIM-IDS simulation works equally well with ModSAF entities as with manned simulators, tradeoff studies could also be run using ModSAF as a DIS-based constructive simulation. Finally, because the DoD is transitioning to a standard High Level Architecture (HLA) from its current DIS simulation standard, MultiSIM-IDS will need to be made HLA compliant. HLA compliance requires incorporation of a Real-Time Interface (RTI) and definition of the simulations interface components in a Simulation Object Model (SOM).